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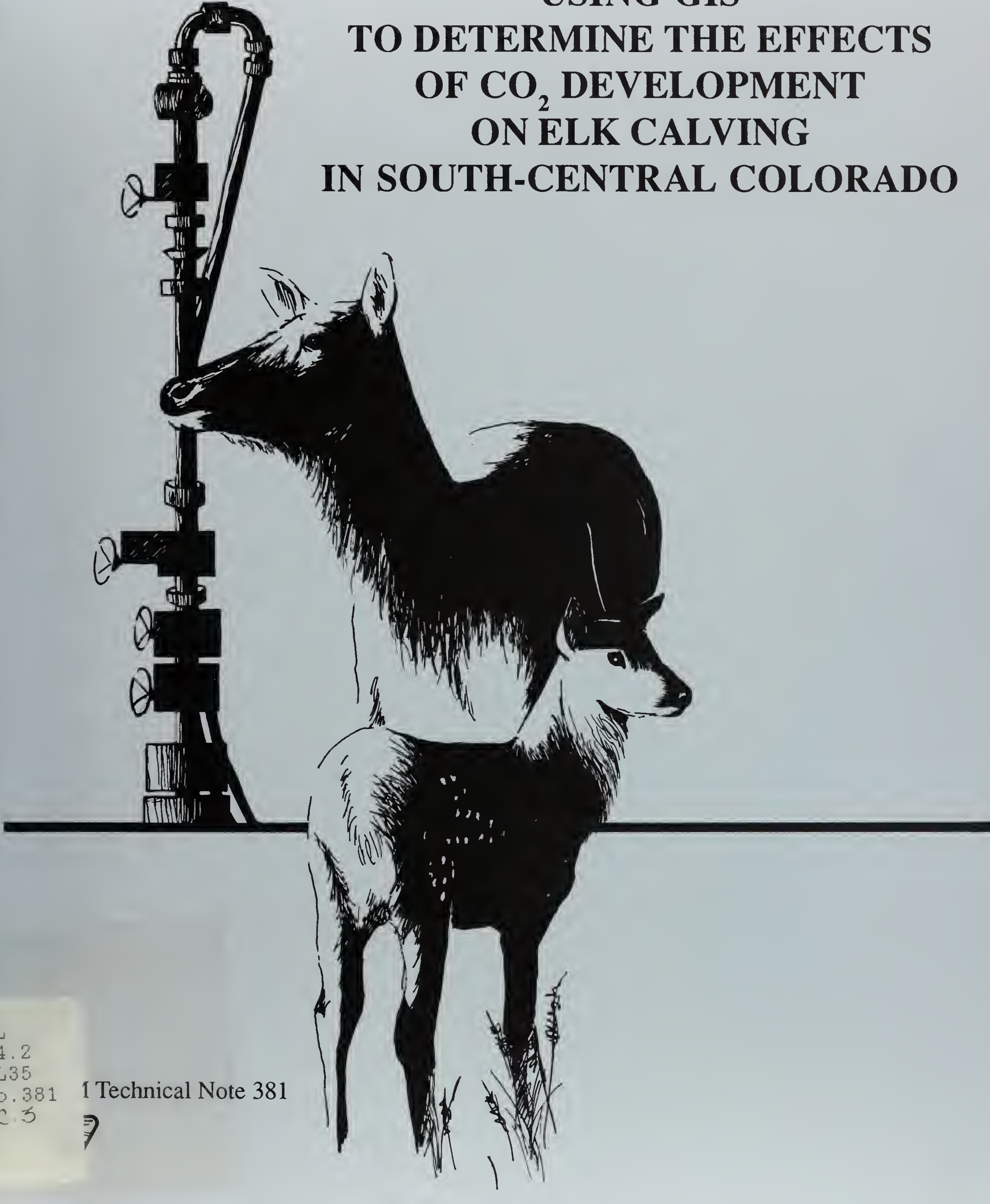

M Technical Note 381

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USING GIS TO DETERMINE THE EFFECTS OF CO_2 DEVELOPMENT ON ELK CALVING IN SOUTH-CENTRAL COLORADO

By

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TABLE OF CONTENTS

LIST OF FIGURES

Note: The GIS graphics included in this report were developed with a pen plot command, but were modified to accommodate offset printing requirements.

LIST OF TABLES

Page

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INTRODUCTION

In 1977 and 1978 the Bureau of Land Management (BLM), Canon City District Office conducted resource inventories to be used in completing the Raton Basin Unit Resource Analysis (URA) and Management Framework Plan (MFP). In the planning inventory, an important elk wintering and calving area was identified by BLM biologists and Colorado Division of Wildlife (CDOW) personnel. Due to the importance of the area to calving elk, BLM completed the Mt. Mestas Off-Road Vehicle (ORV) Plan in 1979. This plan prohibited vehicular travel on public lands in the area during May and June. Vehicular use was restricted to existing roads the remainder of the year.

During this time ARCO Oil and Gas Company, a division of Atlantic Richfield Company, was exploring and test drilling a CO_2 gas field in the area covered by the ORV closure. Soon ARCO began to develop plans on the Sheep Mountain CO_2 field to allow the extraction, purification, and compression of CO_2 gas for transportation to oil fields in west Texas. These plans called for construction of drill sites, roads, and production facilities within the closed area.

BLM contended that ARCO's operation might adversely affect elk calving on the leased area. Therefore, in 1980, ARCO contracted with LGL Ecological Research Associates (LGL) to determine the timing of elk calving and the distribution of calving activity on the leases. The purpose of the study was to evaluate whether the BLM closure of public lands might be modified to ARCO's benefit without adversely affecting the elk herd.

In 1981, with funds contributed by ARCO, BLM took the lead on the elk study. The purpose of this study was to collect additional data and compare results with 1980 data.

In 1982, ARCO requested a variance to conduct drilling activities within the calving area during the calving season. BLM issued the variance when ARCO agreed to continue with the elk study. ARCO contracted Woodward-Clyde Consultants to study the effects of full-scale drilling activities on elk calving and to record elk responses to associated human disturbances such as use of roads and construction activities within the calving area. Unforeseen delays in the drilling program enabled ARCO to avoid drilling during the calving season in 1982; however, construction activities continued. Woodward- Clyde biologists continued observing and recording elk sightings as in previous years.

In 1983 and 1984, the amount of construction and operation activity was reduced on the lease area. Construction of facilities was nearing completion and drilling activities were on hold. BLM and Colorado Division of Wildlife personnel continued collecting data and monitoring the elk herd and calving areas.

In 1985, ARCO requested a variance to conduct drilling activities on Drill Site 5 during the calving season. BLM issued the variance with plans to continue monitoring elk responses to drilling activities. ARCO contributed funds for continuing the study program.

This report describes the methods used in this study to estimate the response of calving elk to ARCO's CO_2 development activities and the use of GIS to assist in estimating elk response to the development.

STUDY AREA

Description

The project area is located approximately 5 mi. (8 km) northwest of La Veta, Colorado in Huerfano County (Figure 1). The two lease areas involved in this study are contiguous; the Sheep Mountain Unit encompasses approximately 32 mi² (82 km²) and the Dike Mountain Unit is about 53 mi² (135 km²)

The two lease units were the primary areas of investigation in 1980 and 1981 when elk spring range, migration routes and calving sites were being identified. Within these units, a smaller study area was delineated in 1982 to study the direct effects of CO_2 development on elk calving (Figure 1). A description of the larger study area appears first with an additional description of the CO_2 development units following.

The topography of the area is varied, including five major mountains (Sheep, Little Sheep, Rough, Silver, and Mestas) and the surrounding foothills, ridges, and lowlands. Elevations vary from about 7,000 ft (2,135 m) to above 11,000 ft (3,350 m). The upper one-third of the mountains in the study area are generally steep-sided with extensive talus slopes. The lower two-thirds of the slopes comprise a complex system of ridges, lesser peaks, small valleys, and open parks.

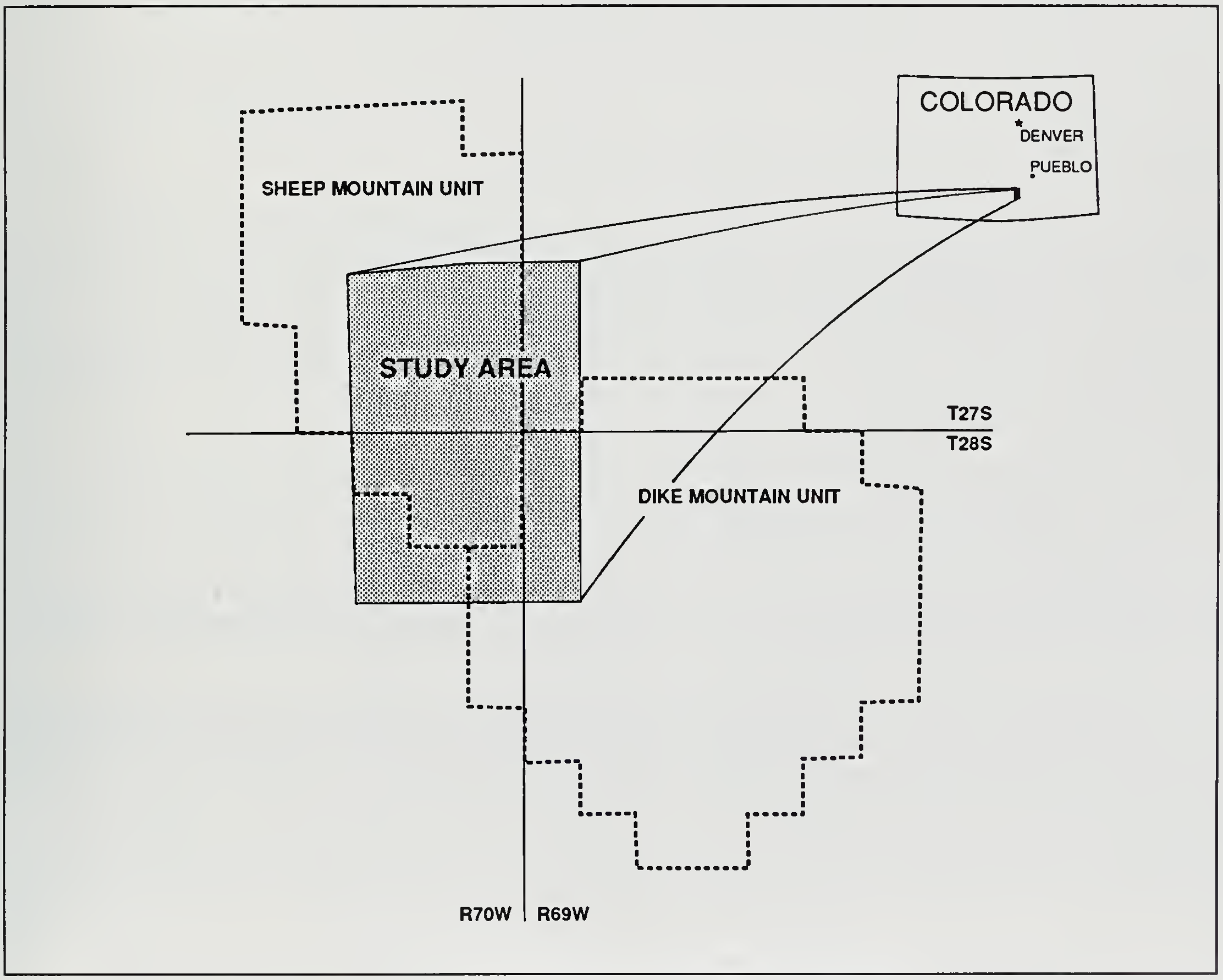

Figure 1. Study Area

The study area is located in a region that has an arid to semiarid continental climate, with relatively cold winters and short, hot summers. There is abundant sunshine, relative humidity is low, and evapo-transpiration rates are high. The high mountains and complex topographic features play an important role in modifying local weather. The mountains in the study area receive relatively large amounts of snow and westerly winds are often strong because of the funnelling effect of the mountains and valleys.

Water is well distributed throughout the study area as springs, intermittent streams, and stock ponds. Significant creeks include Oak, Yellowstone, Pass, and Abeyta. Water was available throughout the study period although the volume varied depending on snowmelt.

Vegetation

The vegetation of the study area is complex, with five major vegetation types present. Vegetation types on the area include mountain grasslands, mountain shrub, pinon-juniper (*Pinus-Juniperus*), aspen (*Populus tremuloides*), and conifer. Grass-forb meadows are locally common in gentle valleys and drainages within the aspen-conifer types (Table 1).

Table 1. Vegetation Types in the Study Area

Vegetation Type	Acres	(Hectares)	Percent
Mountain Grassland	3,948	(1,599)	26
Mountain Shrub	3,740	(1,514)	24
Conifer	3,740	(1,514)	24
Aspen	1,702	(689)	11
Talus	1,190	(482)	8
Wet Meadow	1,008	(408)	6
Pinon-Juniper	272	(110)	1
Total	15,600	(6,316)	100

Mountain grasslands exist on the lower, less steep slopes with deep soils. They are seldom found higher than 8,000 ft (2,440 m) The mountain grassland habitat type can be segregated into the shortgrass subtype of the more arid lower elevation and the midgrass-forb mix of wetter mountain meadows.

The shortgrass subtype is one of the more common vegetative types in the study area, occurring in pockets at both high and low elevations. Blue grama (*Bouteloua gracilis*) is the major species within this type at the lower elevations. Species occurring in lesser amounts include western wheatgrass (*Agropyron smithii*), little bluestem (*Schizachyrium scoparium*), squirreltail (*Sitanion hystrix*), red three-awn (*Aristida longiseta*) and junegrass (*Koeleria cristata*). At higher elevations the dominant species are Arizona fescue (*Festuca arizonica*) and mountain muhly (*Muhlenbergia montana*), intermingled with lesser amounts of other cool season species.

The wet meadow subtype constitutes a small percentage of the study area, but can be located in isolated pockets at all elevations. Production capability of meadow sites is extremely high making them very important foraging areas for elk. Dominant species are sedge (*Carex* sp.), rush (*Juncus* sp.), bluegrass (*Poa* sp.), dandelion (*Taraxacum officinale*), and cinquefoil (Potentilla sp.).

The mountain shrub type is dominated by oakbrush (*Quercus gambelii*) and is generally found on the lower mountain slopes and foothills in the transition zone between the conifer and grassland or pinon-juniper. Predominant species of this type include skunkbrush (*Rhus trilobata*), mountain mahogany (*Cercocarpus montanus*), ribes (*Ribes* sp.), snowberry (*Symphoricarpus* sp.), and chokecherry (*Prunus virginiana*).

The pinon-juniper type occurs in the foothill areas of the study area, generally below the mountain shrub type. Colorado pinon pine (*Pinus edulis*) and Utah juniper (*J. osteosperma*) are the major species. The understory is sparse, but usually includes grasses such as blue grama, Indian ricegrass (*Oryzopsis hymenoides*), three-awn, and needle-and-thread (*Stipa comata*).

The aspen type occurs in isolated populations at higher elevations within the conifer type. It is found in riparian areas bordering mountain meadows and parks and interspersed with conifers on suitable soils. Dominant species include aspen with an understory of blue spruce (*Picea pungens*), Douglas-fir (*Pseudotsuga menziesii*), woods rose (*Rosa woodsii*), and creeping juniper (*J.communis*).

The conifer type is found at higher elevations in the study area. Douglas- fir and ponderosa pine (*P. ponderosa*) constitute the main species in this type. Limited amounts of white fir (*Abies concolor*), Engelmann spruce (*P.engelmannii*), lodgepole pine (*P. contorta*), and bristlecone pine (*P.aristata)* are present. The understory is usually sparse in this type and is dominated by Arizona fescue.

The vegetation types described earlier in the description of the larger study area also apply to the smaller study area. Vegetation types are depicted in Figure 2.

Wildlife

Elk habitat adjoins the study area on the south and west, but not on the north and east. Habitats to the south are similar to those on the study area and elk are common there (L. Brown, Colorado Division of Wildlife, La Veta, pers. commun.). To the west are high mountains where some elk from the study area migrate in the summer. Suitable elk habitat does not exist to the north and east. Other big game animals common to the area include mule deer (*Odocoileus hemionus*), mountain lion (*Felis concolor*) and black bear (*Ursus americanus*).

Land Status and Ownership

The study area encompasses approximately 15,600 a (6,313 ha) (Table 2). Surface resources are approximately 72 percent privately owned, 4 percent state owned, and 24 percent federally owned (Figure 3).

Table 2. Land Status and Ownership in the Study Area

Land Status	Acres	Hectares	Percent
Public Lands	3,772	1,527	24
State Lands	640	259	4
Private Lands	11,188	4,527	72
Total	15,600	6,313	100

ARCO CO_2 Project Description

ARCO Oil and Gas Company, a Division of Atlantic Richfield Company, has developed the Sheep Mountain CO_2 Field to allow for the extraction, purification, compression, and transportation of 300 million standard cubic feet per day (MMscfd) of CO_2 to oil fields in west Texas. The CO_2 is used to enhance the recovery of oil from existing petroleum fields. Tertiary recovery in the vast west Texas oil fields using the CO_2 injection process is expected to provide approximately 3 to 4 billion barrels of previously unrecoverable petroleum. CO_2 from the Sheep Mountain field is expected to provide approximately 5 to 10 percent of that total over the next 20 years.

Development of this gas field required over 30 wells directionally drilled to depths ranging from 4,000 to 5,000 ft (1,219 m to 1,524 m) below the surface. Twenty-nine of these wells are clustered in groups of five or six on five centrally located drill sites. The remaining five wells are single wells located at remote sites around the unit. Processing (purification) and compression facilities are installed at each drill site to handle the gas from that group of wells and one or two nearby remote wells, as appropriate. A minimum amount of control and heating equipment is installed at each remote site. All drill sites receive electrical service from a privately owned 115 kv powerline originating from a substation near the town of Walsenburg, approximately 22 mi. (35 km) east of the unit. Remote wells receive service from a privately owned 12.5 kv powerline originating from substations on the nearest drill site. All CO_2 is gathered from each well and delivered to a meter station at the eastern edge of the unit using approximately 13 mi. (21 km) of buried pipeline ranging in diameter from 12 to 20 in. (30 to 51 cm). The CO_2 is transported from the meter station at the eastern edge of the unit to western Texas (approximately 400 mi. or 644 km) through a 20-in. (51-cm) buried pipeline. All drill sites and remote well locations are connected by a system of all-weather roads.

The Sheep Mountain CO_2 Field was developed between 1981 and 1985. Activities in each phase were submitted under separate sundry notices, subject to on-site inspections by both United States Geological Survey (USGS) and BLM personnel and either approved, modified, or not approved. Reclamation and maintenance operations have been an integral part of the approval of each phase.

Abandonment operations will take place at the end of the useful life of any or all facilities within the unit, approximately 15 to 25 years. Facilities will be removed, wells will be plugged as abandoned, and pads and roads will be recontoured and revegetated according to the desires of the surface owner and under the guidance of BLM (USGS 1981).

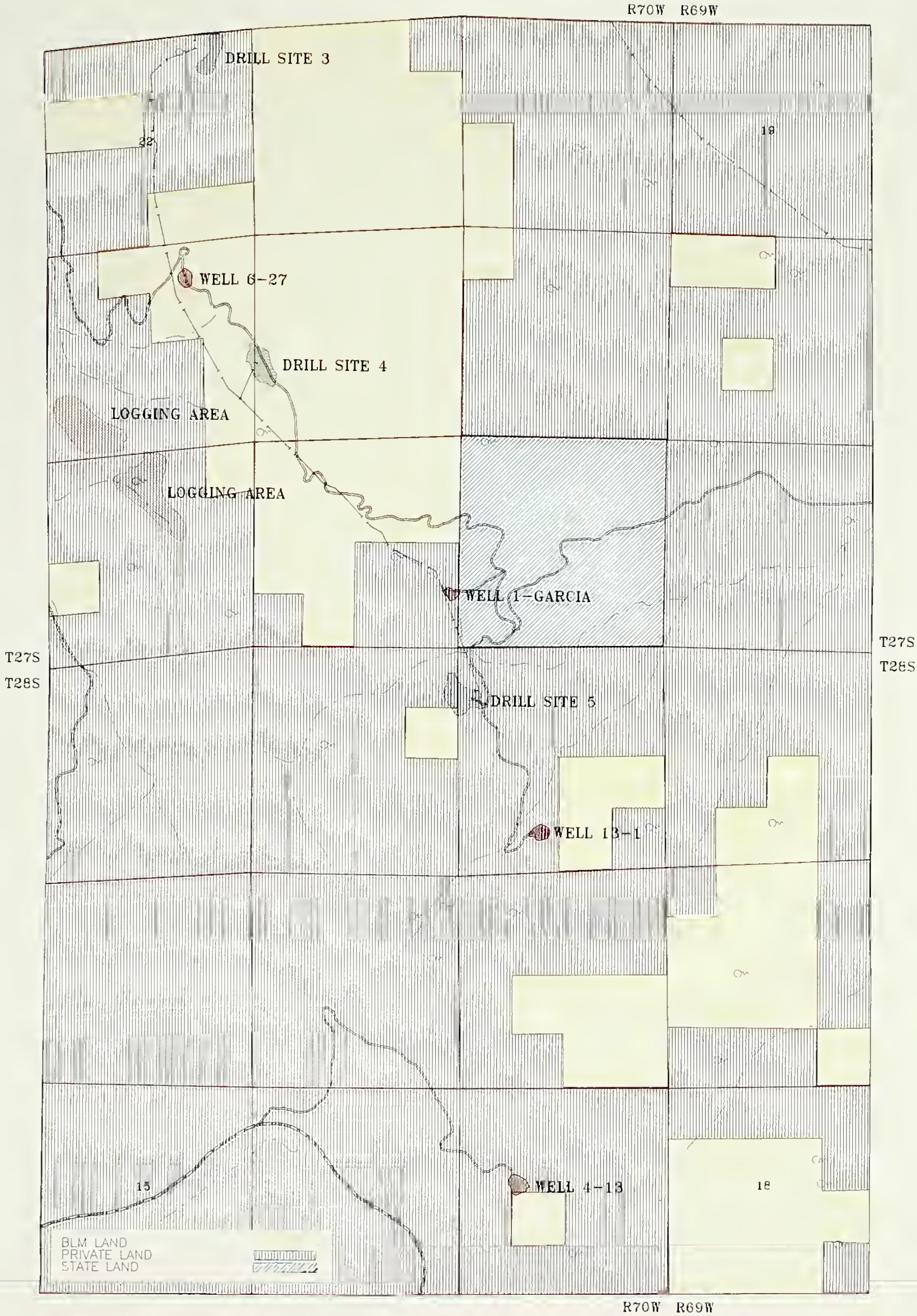

Figure 2. Land Status of Study Area.

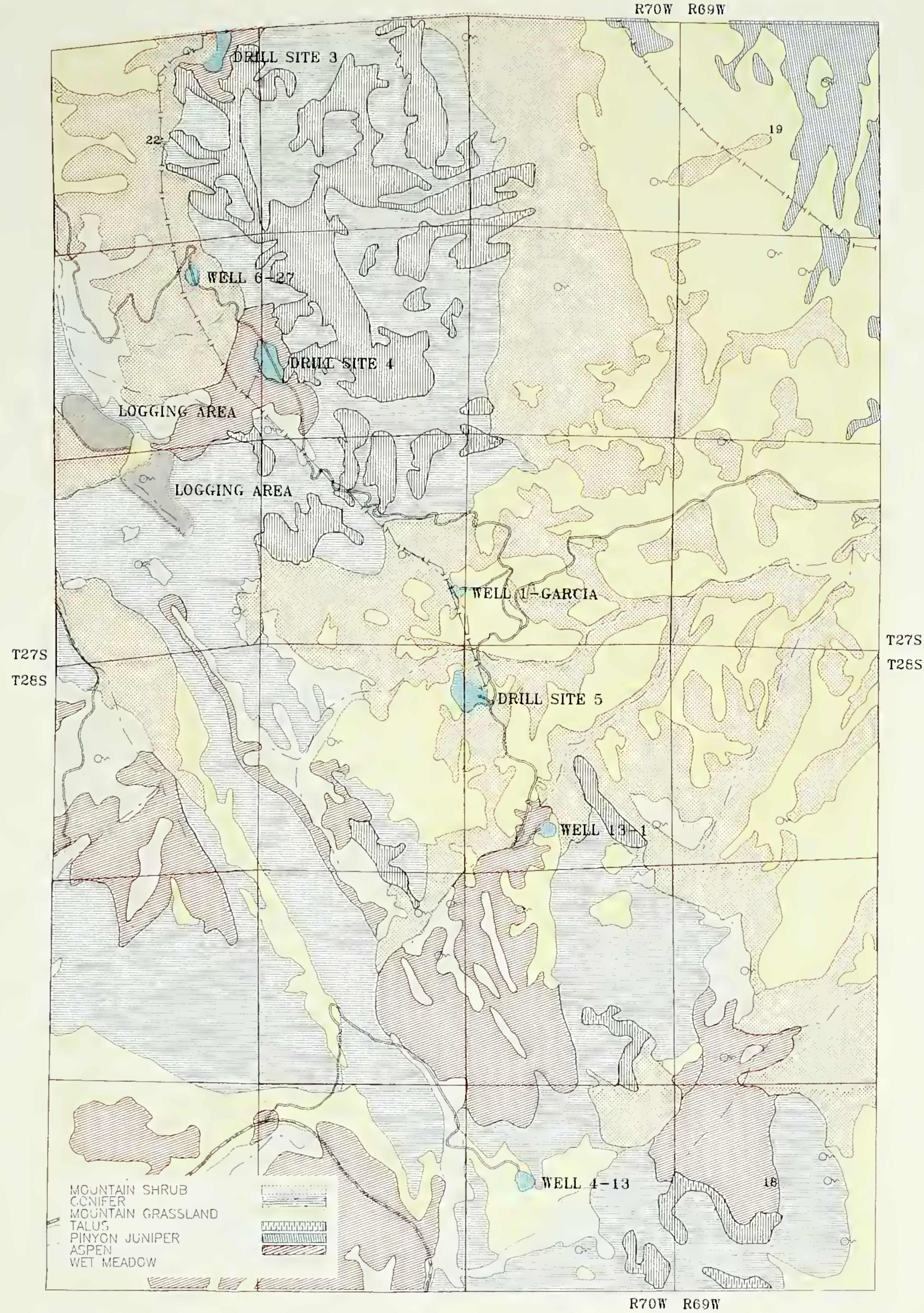

Figure 3. Major Vegetation Types in the Study Area.

METHODS

Geographic Information System

A computerized Geographic Information System (GIS) approach was used to analyze much of the data collected for the study. A GIS is an information system that captures, stores, and analyzes geographic or spatial information.

The GIS retains geographical integrity by using a coordinate reference system, usually latitude and longitude. It works with symbolic representation of the earth. It stores, analyzes and displays the geographic reference data and it performs cyclical processing which is used in cartographic modeling.

The GIS used in this study was the Department of Interior's Map Overlay and Statistical System or MOSS. MOSS, as with most GISs, consists of three basic subsystems. These are data entry, data analysis, and cartographic output. Data entry is the process of converting map data into computer data. The automated mapping system (AMS) was used to electronically encode point, line, and polygon information into geographic coordinates via the process of digitizing.

Digitizing is basically electronic tracing. Subject information such as drill site names and vegetation types, is added so that the GIS data base contains not only points, lines, and polygons but descriptive information as well.

For this study, several themes were digitized: land status, roads, pipelines and drill sites, water sources, vegetation types, and elk sightings for all six years.

Once captured in the computer, the data was visually displayed on a graphics terminal and manipulated with analytical programs in the MOSS subsystem. In MOSS, there were over 170 analysis commands that performed operations ranging from simple area and distance calculations to more sophisticated cartographic modelling through mathematical manipulation of the map data. The Penplot and Zeta commands in MOSS were used to prepare the cartographic quality maps for use in this report and in meetings and displays.

Digital Elevation Models (DEMs) were utilized to determine elevation, slope, and aspect for all elk sightings. The DEMs also produced viewshed analyses (areas within the line of sight), a contour map, and three-dimensional representations of the study area.
The analysis done for this study included:

1. Acreage calculations of habitat types and land ownership.
2. Mileage summaries of roads, pipelines and powerlines.
3. Elk distribution within habitat types.
4. Elk distribution within 0.25 - 1.50 mi. (0.40 - 2.4 km) zones around the selected drill sites.
5. Elevation class of elk sightings.
6. Aspect of elk sightings.
7. Slope class of elk sightings.
8. Viewshed determination for the selected drill sites.
9. Elk distribution within buffer zones compared between years and habitat types.
10. Elk distribution within the selected drill sites viewsheds compared between years and habitat types.

Aerial Surveys

Aerial surveys were made both from a fixed-wing aircraft and from a helicopter. A total of 30 flights were made during the May-June study period from 1980 to 1985. A fixed-wing aircraft was used on eight occasions early in the spring when large groups of elk were in open, relatively flat terrain. Helicopters were used when elk broke into smaller groups and moved into more dense habitats. The cost of these aerial flights was a major consideration and the less expensive airplane was used in the early flights despite the fact that a helicopter is more effective for surveying elk (Norberg, 1956).

All aerial surveys, with the exception of an occasional flight delayed due to weather, were flown from approximately sunrise to 2 or 2-1/2 hours after sunrise. A total of 65 hours of aerial survey time was recorded for an average of 2.1 hours per flight.

All flights had two to three wildlife biologists as observers. Some assistance in elk spotting was provided by the various pilots, depending on flying conditions, interest, and experience.

A flight pattern was selected that would allow the observers to view essentially all areas likely to contain elk. Rather than flying sample transects, aerial surveys were conducted covering all the elk habitat within the lease areas.

The initial survey pattern of north-south and east-west contiguous strips proved ineffective due to problems encountered with the topography of the area. Many of the ridges and valleys were oriented perpendicular to the flight path, which prevented the pilot from maintaining an optimum altitude for visibility. Fewer problems were encountered in maintaining an appropriate altitude when the survey was conducted drainage by drainage. This pattern made it possible to avoid severe winds and downdrafts common in certain locations of the study area.

During aerial surveys, data were recorded onto topographic maps with notes on separate forms as to numbers of elk, habitat types, sex, etc. When possible, data on sex and age of elk were recorded. It was difficult early in the study period, when flying, to reliably distinguish young bulls, cows, and yearlings.

Ground Survey

Ground surveys were normally conducted after aerial surveys for two reasons. First, disturbance of elk from ground survey efforts might have influenced the results of follow-up aerial surveys. Second, the aerial surveys indicated the most productive ground survey areas (LGL 1980).

Ground surveys were used to verify and/or augment aerial survey data as well as check areas not surveyed from the air or where the canopy was too dense to provide adequate visibility from the air.

To conduct ground surveys, biologists traveled to areas where elk had recently been seen from the air, usually on the same or succeeding day. One to four biologists walked through the area observing tracks and droppings and stopping from time to time at vantage points to look for animals. When elk were seen, the observers counted and, if possible, classified them by sex and age, and tried to evaluate by the behavior of adult females or by direct search whether or not there were calves in the vicinity. Locations and brief descriptions of each elk group and the distribution and abundance of recent elk sign encountered were noted on topographic maps.

Estimating Population Size

Estimates of the number of elk existing on the study area were made using three methods: (1) LGL (1980) estimated population size on the study area by a ratio estimator based on the number of collared vs. uncollared elk seen on aerial flights (elk had been collared in the area by the Colorado Division of Wildlife); (2) by using a ratio of ground counts vs. aerial counts in the same area on the same day; and (3) by estimating the population based on the assumption that helicopter counts tallied 50 to 70 percent of the elk actually present (Woodward-Clyde Consultants 1983; Boyd 1958; Gilbert and Grieb 1957).

There was considerable variation among aerial survey counts both within individual survey periods and between years. This variability is to be expected due to differences in survey aircraft, experience of pilots, flight conditions (weather), plus differences among surveys in vegetative cover, stage of vegetative development, and terrain where elk were located.

Variability in year-to-year precipitation, primarily snowpack and rate of snowmelt, resulted in different population estimates for corresponding survey periods from year to year. LGL (1980) judged the variability among survey times (numbers of elk seen) was so great that it was unreasonable to try to obtain a total population estimate by averaging the results of all surveys. Hence, population estimates for each year were made with data obtained in one survey period. The number of elk was also estimated by using the ratio estimator known as the Petersen or Lincoln index that is applied to the proportion of collared vs. uncollared elk seen. The Colorado Division of Wildlife had collared 29 elk (15 in January 1970, 2 in January 1980, and 12 in January 1984) in the area. The following assumptions were made:

1. No elk collared on the study area were outside the area during the study period.

2. The collared elk were randomly mixed within the study area population.

3. Four collared elk were known to have been killed (two in 1979 and two in 1984). It was assumed that the herd experienced a 25 percent annual adult mortality throughout the study period (1980 through 1985). With this in mind it was determined that the number of collared elk in the population was 12 in 1980, 9 in 1981, 7 in 1982, 5 in 1983, 14 in 1984, and 10 in 1985.

The following formula was used to calculate population size using this method:

(Formula 1)

$$\frac{\text{collared elk in herd}}{x} = \frac{\text{collared elk observed}}{\text{uncollared elk observed}}$$

Results of ground surveys conducted on a portion of the study area were used to estimate the proportion of the total herd seen from the air on the same day. Population estimates using this method were calculated for May 21, 1980; May 27, 1981; May 26, 1982; May 25, 1983; and May 29, 1985. Lack of ground survey for the May 22, 1984, period prevented using this method for that year. The following assumptions were made:

(1) No appreciable movement of elk occurred during that day,

(2) Essentially all elk in the area surveyed were seen during the ground survey, and

(3) During the aerial survey the same proportion of the total elk population was seen at all locations. A rough estimate of the total elk population (x) was made using this formula:

(Formula 2)

$$\frac{x}{\text{elk seen in the study area from the air}} = \frac{\text{elk seen during ground survey}}{\text{elk seen in the ground survey area from the air}}$$

The last method used to estimate population size was based on aerial census efficiency. The number of elk seen from helicopter surveys was recorded for the following dates:

May 21, 1980; May 27, 1981; May 26, 1982; May 25, 1983; May 22, 1984, and May 29, 1985. Estimates were based on the assumption of 50 to 70 percent census coverage efficiency from a helicopter as reported by Boyd (1958) and Gilbert and Grieb (1957). An average of 60 percent efficiency was used for this paper (Formula 3).

Determination of Elk Movement Patterns

Patterns of elk movements in the study area were determined from a combination of aerial and ground survey data. The primary spring migration routes were identified by LGL (1980) and verified with additional data collected in the spring from 1981 through 1985. Aerial surveys provided a weekly picture of elk distribution in the study area. The ground surveys provided additional information in the form of tracks, droppings, etc., indicating general movement patterns.

Determination of the Timing of Calving and Delineation of Calving Areas

Timing of elk calving was primarily determined by observations of calves within the study area, estimating their age and backdating to determine birth date. These observations were in addition to observing the behavior of adult cows and determining when they halted their spring migration movements. Calving areas were delineated by plotting the distribution of adult females that, judging by the calendar date of the survey and by behavior of the elk, were near parturition time (LGL 1980). Additionally, observations of elk and calves and signs such as tracks were used to define calving habitats. A review of literature concerning elk calving habitats enabled biologists to concentrate on probable calving areas.

Determination of Elk Precalving Migration Movements in Relation to Annual Precipitation Patterns

A sufficient number of flights and follow-up ground surveys were conducted in 1980 and 1981 to accurately document weekly shifts in habitat use and elk distribution. Weather records for 1980 and 1981 from the weather station at Walsenburg were examined to determine if any relationship between precipitation and elk distribution and shifts in distribution during May and June could be discerned.

Determination of Distribution of Calving Elk in Relation to Drill Site Activities

To determine if calving elk were affected by development activities on the drill sites, a smaller study area in which elk observations were recorded (1982 through 1985) was delineated. This area included Drill Sites 4 and 5; the access road between the drill sites; and auxiliary wells 6-27, 1-Garcia, 13-1, and 4-13 (Figure 2). Activity at the auxiliary wells was minimal and was not considered to be a major influence on elk.

Data collected from this smaller study area included vegetation typing; mapping of water sources and ARCO facilities including roads, drill sites, pipelines, auxiliary wells; and mapping land status in addition to recording all elk observations for May and June of 1980 through 1985. ARCO activities at Drill Sites 4 and 5 were recorded for each year during the May-June study period.

RESULTS

Population Size

A total of 327 separate group sightings consisting of 2,076 individual elk were mapped for the entire study period. Table 3 shows the results of the population estimates made with each of the three methods discussed in the "Methods" section of this report. The variability among aerial surveys in numbers of elk seen was due to differences in weather, vegetative types, and differences in dispersion of elk in the study area. The low count on elk seen during the May 27, 1981, survey resulted from a late arriving helicopter and refueling problems. This low elk count resulted in a significantly erroneous population estimate using the 60 percent efficiency method. A population estimate using the ratio of collared:uncollared elk observed was unavailable for the survey period May 26, 1982, because sightings of collared elk were not distinguished from uncollared elk. Finally, a population estimate was unavailable for the May 22, 1984, survey period using the method of comparing ground and air surveys because ground surveys were not completed on the same day as the flight.

Table 3. Elk Population Estimates in the Study Area, 1980-1985

Year	Date of Flight	Elk Observed	Population Estimates Calculated By:		
			Formula 1 Petersen Index	Formula 2 Ratio of Air/ Ground Surveys	Formula 3 Efficiency of Aerial Counts
1980	May 21	216	353	385	360
1981	May 17	43*	378	365	71*
1982	May 26	196	**	437	326
1983	May 25	294	584	280	490
1984	May 22	259	504	♦	431
1985	May 29	145	725♦♦	290	203
Average		222	508	351	314

* *Figure not included in average because helicopter was late and flight was interrupted for refueling.*
** *Collared elk were not distinguished from uncollared elk during flight.*
♦ *Ground surveys were not completed on same day as flight.*
♦♦ *Figure is high because only a few collared elk were observed on the flights.*

The figures in the table show that population estimates vary not only between years but between methods within years. The variability is related to the difference in elk observed for each flight date. Estimates made for 1980 through 1982 are similar, averaging 372 animals. Estimates for 1983 and 1984 are somewhat higher because of the large numbers of elk seen on the survey dates (294 and 259 respectively). These large numbers result from elk still being grouped on their winter range rather than distributed throughout the study area. Migrations of elk to the calving areas varied between years depending on snow condition and weather patterns. Based on the figures displayed in Table 3, an estimated average of 508 elk were present in the study area for 1980 through 1985 (Column 4).

Elk Distribution and Movement

Elk movement patterns in the study area were determined from observed shifts in elk distribution during the May-June study period for 1980 through 1985 (Figure 4). Elk distribution was evaluated according to locations of sightings from the air and the ground. Movement patterns and distributional limits remained essentially unchanged during the study period. The timing of migration to adjacent habitats varied depending on weather conditions, as discussed later in this report. The elevational distribution of elk on the study area also varied, for the same reason.

Observations of elk during May and June for the past 6 years suggest that the movement routes shown in Figure 4 are the major ones. No evidence indicated that elk in the study area moved in directions other than northwest, west, or southwest. Observations indicated that elk avoided high, steep ridges or mountains (e.g., Sheep Mountain, Dike Mountain, Mount Mestas) as they moved west.

Timing of Calving

Migrating female elk nearing parturition commonly disassociate themselves from other elk and stop their migratory movements (Altmann 1952; de Vos et al. 1967). Decreasing group size, cessation of migratory movements, and estimates of ages of calves observed in June suggested that the timing of parturition among elk was similar to that reported for other herds in Colorado.

Boyd and Ryland (1971) determined that the elk calving period in the San Juan Basin of southwestern Colorado extended from approximately May 24 to July 6, with a mean date of June 14.

Sweeney and Steinhoff (1976) found calving to occur (1970 to 1974) between "mid-May to mid-June" in the San Juan Mountains of southwestern Colorado.

Similar calving periods have also been recorded in western Montana (Johnson 1951; Reichelt 1973).

Throughout the study period, elk group size decreased from early May to the last week in May and remained fairly constant from then until late June. Despite variations in weather patterns and snow conditions between years, most of the elk in the study area had stopped their precalving movements by the end of May each year. It is apparent from June survey results that appreciable numbers of elk did not begin moving away from the calving areas until after the third week in June. Altmann (1963) estimated calves in Wyoming to be 18 to 20 days old before they were old enough to travel.

During the course of this study, 156 calves were observed in the study area. Of this number, 22 were observed at close range and a reasonably accurate estimation of age was made. The earliest a calf was seen was June 4, 1981, and it was estimated to be 2 weeks old. The majority of calves observed were seen from approximately June 9 to June 14 and were estimated to be 2 to 3 weeks old. If estimates are correct, the oldest of these calves would have been born sometime between May 20 and 30.

Estimates of calving seasons were made by LGL (1980), May 20 to July 1; BLM (1981), May 17 to June 26; Woodward-Clyde Consultants (1983), May 25 to June 20, for this study area. These estimates are similar to those made for calving periods in other areas of Colorado (Boyd and Ryland 1971; Sweeney and Steinhoff 1976).

The estimated calving dates in the study period 1980 through 1985 are May 20 to July 1.

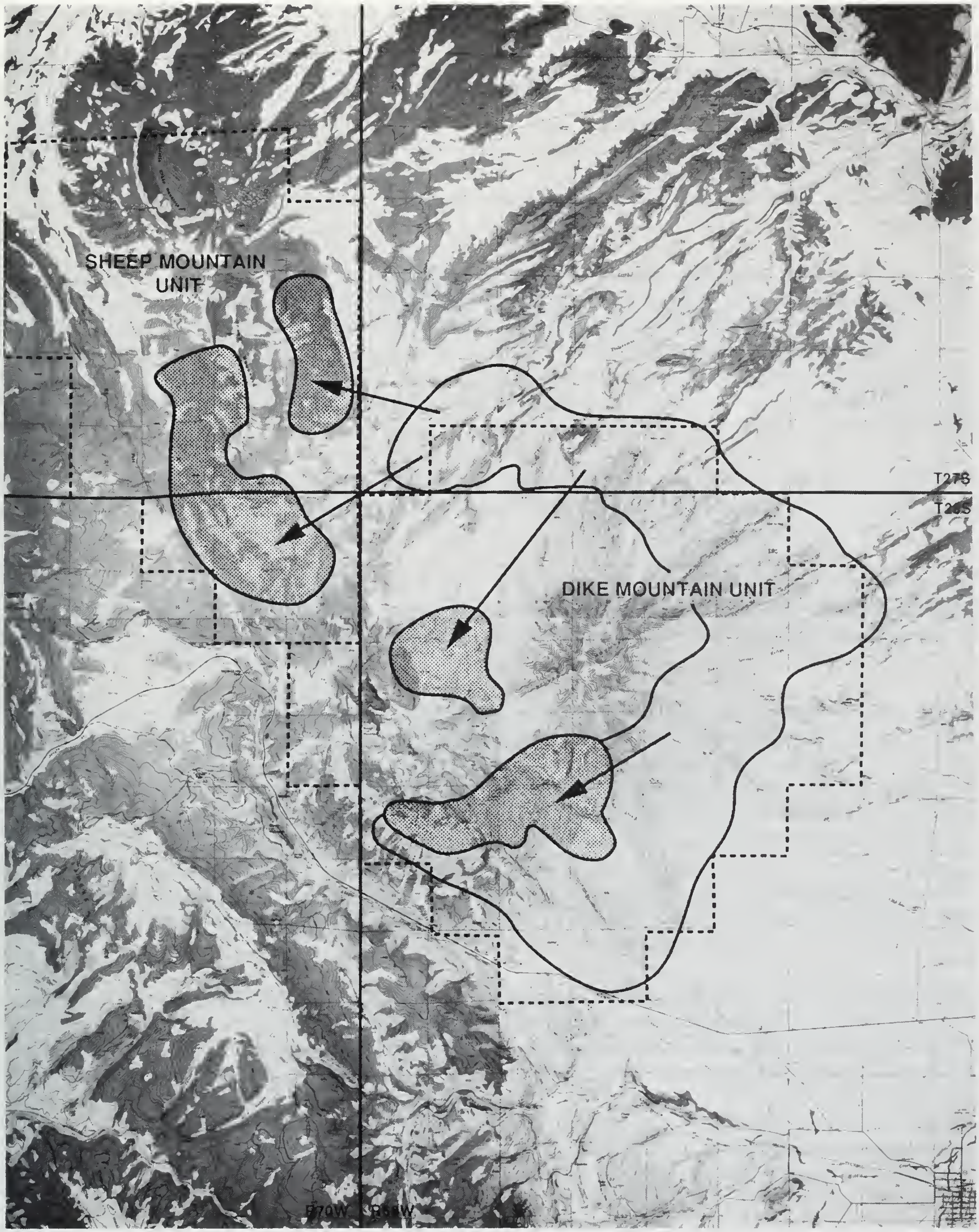

Figure 4. Elk Migration Routes

Calving Areas and Habitats

Migrating elk cows temporarily halt their movements toward summer range to give birth and wait until the calves are able to travel. Elk that halt spring migration to give birth remain in the calving area for 3 weeks or more (Altmann 1952; Anderson 1958; Bendt 1962). This pause for calving occurs when cows separate from the herd to seek a calving locality prior to parturition (Altmann 1952) and while waiting for newborn calves to become mobile (Brazda 1953). The length of this pause was estimated to be 3 weeks for Jackson Hole, Wyoming elk (Altmann 1952) and 4 weeks for elk in the Madison River drainage in Montana (Reichelt 1973).

Elk cows in this study stabilized their movements from approximately May 25 until June 14. During the study period, which included six calving seasons (1980 through 1985), elk in the area exhibited marked shifts in distribution for 2 weeks before and after this 3-week period. Cow elk arrived in the calving areas as early as May 5 (1981) and as late as May 28 (1980). Cow elk had reached calving habitats by May 25 in 1982, 1983 and 1985, but were not in calving areas by May 22, 1984. Differences in the distribution pattern and migratory movements in the study area are expected and probably result from the combined influences of natural environmental factors (e.g., weather, forage availability, and greenup).

The period, May 25 to June 14 when elk movement and distribution stopped, represented the peak of calving during this study. This time also encompasses the estimated peak of the calving period for other elk herds in Colorado (Boyd and Ryland 1971).

Additional methods used to delineate elk calving in this study included observations of fresh elk tracks and droppings observed during the May-June period, noting vegetation types where elk and/or sign was observed and noting proximity to water. A review of literature pertaining to elk calving habitats enabled biologists to identify likely areas.

Optimal calving habitat for elk contains forage areas, hiding cover, and thermal cover within forest stands (Thomas 1979). The primary habitat type in the study area (mixed aspen-conifer forest with interspersed wet meadows) is similar to calving habitats described in other areas of the Rocky Mountains (Johnson 1951; Altmann 1952; Anderson 1958; Boyd 1970; Coop 1971; and Reichelt 1973). In this study, slope, aspect, and elevations were determined for all elk sightings in the study area by analyzing DEMs within GIS. Based on the DEMs, it was determined that most of the sightings in the calving areas occurred on north, northeast, and east aspects (Figure 5). Similarly, a majority of the elk sightings in the calving areas occurred on 10-30 percent slopes (Figure 6). Thomas (1979) reported that calving habitats are usually located where slopes are gentle—usually less than 15 percent. The aspects used by elk were not statistically different on slopes utilized before or after ARCO's development.

In Montana, elk calved from 6,780 ft (2,080 m) to 9,005 ft (2,745 m) in the Gallatin River drainage (Johnson, 1951). In Colorado, calving grounds were reported to be from 9,810 ft (2,990 m) to 10,300 ft (3,140m) on Missionary Ridge in the San Juan Mountains (Sweeney and Steinhoff, 1976), about 10,200 ft (3,110 m) in the Long Ridge area of the Rio Grande National Forest (Boyd, 1970), and between 8,000 ft (2,438 m) and 9,000 ft (2,743 m) in western Colorado (Seidel, undated). Elevations of calving habitats were reported to be from about 8,000 ft (2,438 m) to 9,500 ft (2,896 m) in the study area (LGL, 1980; BLM, 1981). Woodward-Clyde Consultants (1983) reported calving to take place from 8,300 (2,682 m) to 9,200 ft (2,804 m) for the same area. Analyzing DEM data for the study area and comparing results with elk observations for May and June 1980 through 1985 indicate that the majority of the occupied elk calving habitat occurred from 8,000 ft (2,438 m) to 9,500 ft (2,896 m). These elevations are not appreciably different from those reported in other calving areas of Colorado.

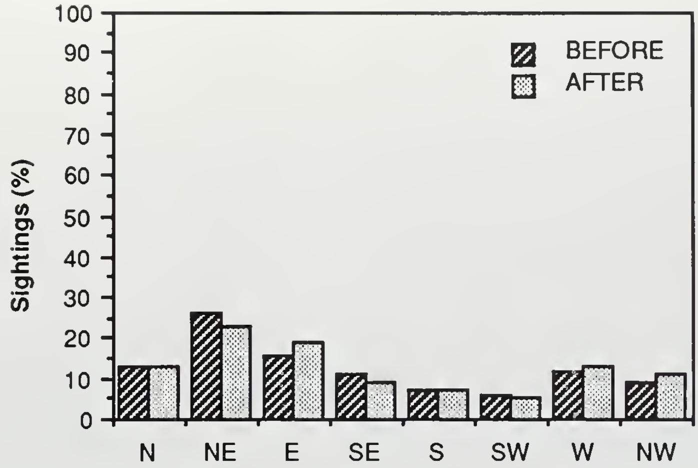

Figure 5. Elk Sightings by Aspect

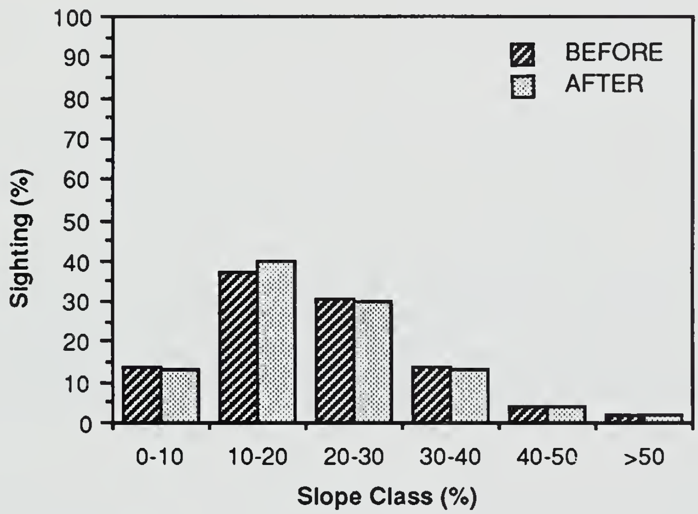

Figure 6. Elk Sightings by Slope Class

Surface water in flowing streams, springs or stock tanks, and ponds was common in all calving habitats within the study area. Thomas (1979) reported that water was available within 1,000 ft (305 m) in most calving areas in the Blue Mountains of Oregon. Few localities in the calving areas were farther than 1,640 ft (500 m) from water in this study area (LGL, 1980). BLM (1981) reported calving areas to be within 1,320 ft (402 m) in the same area and it was determined in this study that a majority of the elk sightings for the May and June time period from 1980 through 1985 were within 1,320 ft (402 m) of water. These data are not significantly different than those indicated by Marcum (1976) who reported a preference by elk for areas within 1,050 ft (320 m) and Scott (1978) who learned that areas greater than 1,350 ft (411 m) from water were avoided in late spring.

Precipitation Patterns and Effect on Elk Migration to Calving Habitats

During 1980 only minor shifts in the distribution of elk occurred between April 28 and May 22, at which time the elk were on winter range (L. Brown, Colorado DOW, pers. commun.). Elk were between 7,200 ft (2,195 m) and 8,400 ft (2,560 m) elevation during the period. Shortly after May 22, however, elk distribution changed drastically so that by May 29 elk were seen at 9,000 ft (2,743 m) elevation and several miles westward of the May 22 distribution. Elk distribution was relatively stable from June 4 through June 14. Elk were observed between 7,900 ft (2,408 m) and 9,300 ft (2,835 m) elevations at this time. Another distributional shift began in late June, at which time elk with their calves moved westward, presumably towards summer range.

During 1981, the first aerial survey (May 5) and subsequent ground searches on May 6 and 7 showed that most elk were distributed at elevations ranging from 7,800 ft (2,377 m) to 9,500 ft (2,916 m), in places they had not reached until late May the previous year. On May 12 and 13, elk distribution was basically the same in elevation, but there had been small scale movements to adjacent habitats. Elk behavior indicated calving had not yet begun. Surveys late in May and through the first half of June showed virtually no change in elk distribution. In late June, as in the previous year, elk with their calves began moving west out of the study area.

A difference was evident between the 1980 and 1981 timing of elk moving to areas where they calved. During 1980, elk arrived in the calving areas sometime between May 23 and 27, but in 1981, elk occupied the same areas by May 5. Timing of post-calving movements remained unchanged from 1980.

Major differences in precipitation were apparent immediately prior to the 1980 and 1981 study periods (Figure 7). Precipitation during the winter of 1979-1980 was above average, with the majority falling in the form of snow. Several major storm systems occurred in October, November, and December of 1979 in the study area. Cold temperatures and additional spring snows resulted in above average snowpack in spring just preceding the calving period. Precipitation during the same time period in 1980-1981 was below normal and the winter was significantly more mild. Many areas normally covered with snow were open for most of the winter. Winter precipitation (September through February) for 1980 was 40 percent greater than 1981 with 5.77 in (14.65 cm) and 3.53 in. (8.96 cm) respectively. Total precipitation for March, April and May for 1979-1980 was 10.66 in. (27.07 cm) and for 1980-1981 5.03 in. (12.77 cm) or about 53 percent less in 1981 then 1980.

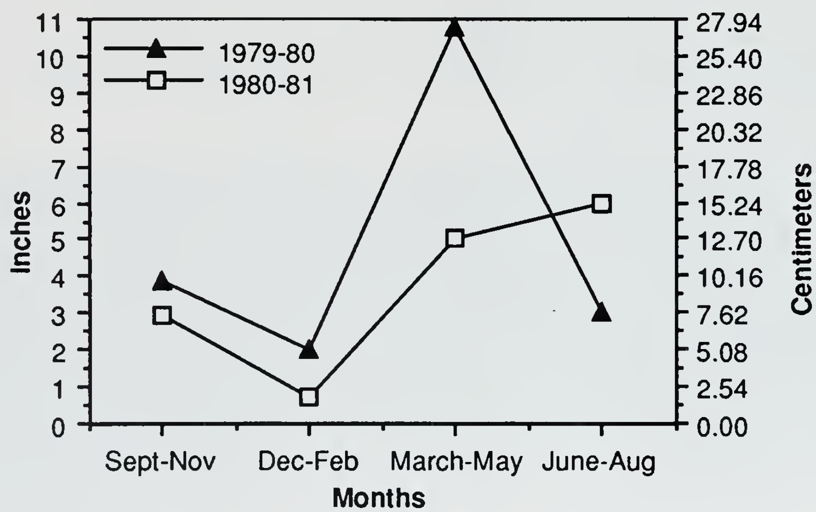

Figure 7. Precipitation Levels for 1980-1981

Differences in winter and spring weather patterns in 1980 and 1981 may have caused the variation in timing of elk migration to calving areas. Warmer temperatures or earlier availability of green forage, or both, may have prompted the early movement to calving areas in 1981.

Several observers report a preference by elk for cool sites in warm weather (Marcum 1976; Scott 1978; Lyon 1979). Warmer temperatures and lack of snow in 1981 in the study area may have influenced elk to retreat to higher elevations earlier than in previous years.

Elk are also responsive to the availability of succulent, green forage. When forbs, sedges, and grasses are most succulent, they are used extensively by elk (Korfhage et al. 1980). As these species mature, elk preference shifts to higher elevation forest habitats where plants retain their succulence and nutrient value (Skovlin 1976). Korfhage et al. (1980) working in Oregon learned that phenological development of plants was 2 to 3 weeks early when spring precipitation was 4 to 5 in. (10-13 cm) below normal. Elk adjusted their schedule of plant usage accordingly, moving into normal spring habitats a month earlier. Similarly, low levels of spring precipitation in the study area in 1981 may have caused forage to become green earlier and the elk to migrate to higher elevations 3 weeks ahead of 1980 migration, when spring precipitation was high and plant growth was retarded. Indeed, plant phenological development in 1981 was a few weeks advanced from that of 1980.

The timing of elk precalving migration appears to be regulated by weather and/or forage phenology. Differences of 2 to 3 weeks in elk migration are possible where annual fluctuations in precipitation are common.

Post-calving movements are constrained by the relatively fixed timing of calving. Until 2 to 3 weeks after birth, calves are not ready to travel with the cows. This migration has approximately the same timing each year despite weather and/or forage conditions.

Effects of CO_2 Development on Calving Elk

Little research has been devoted to assessing influences of oil and gas exploration and development activity on wildlife (Knight 1980). A number of investigators have documented that elk move away from activities such as logging, road building, and activity along roads (Roberts 1974; Black et al. 1976; Lyon 1979; Rost and Bailey 1979). Johnson and Lockman (1981), working in Wyoming's Snider Basin investigated the response of elk during calving to oil and gas drilling activities. They determined that elk responded to activity associated with drilling in Snider Basin by avoiding roads and the drill sites. In addition, they observed that cow elk moved their calves at an earlier age away from the source of disturbance. Lyon (1975) and Thomas (1979) found that elk were displaced from one cover type to a comparable cover type that was buffered from the source of disturbance by barriers such as ridges, hills, mountains, or stands of timber suitable for escape cover. Distances that elk moved to avoid disturbances, as reported by a number of researchers, depend largely on these barriers and the arrangement of foraging areas relative to cover.

In this study, the sources of disturbance which were located in the elk calving area consisted of two 12 a. (4.8 ha) drill sites, 12 mi. (19.3 km) of access road and 6 mi. (9.6 km) of pipelines and powerlines (Figure 8). Major construction of these facilities began in the fall and winter of 1981 and continued through the calving season of 1982. It was during the May-June calving season of 1982 and 1985 that the most significant disturbances to the elk herd occurred as evidenced by comparing elk movements prior to and during operations.

A variety of construction activities on Drill Site 4 occurred during the calving season in 1982. Construction of the drill pad was completed prior to the calving season; however, reserve pits were being constructed during May and June.

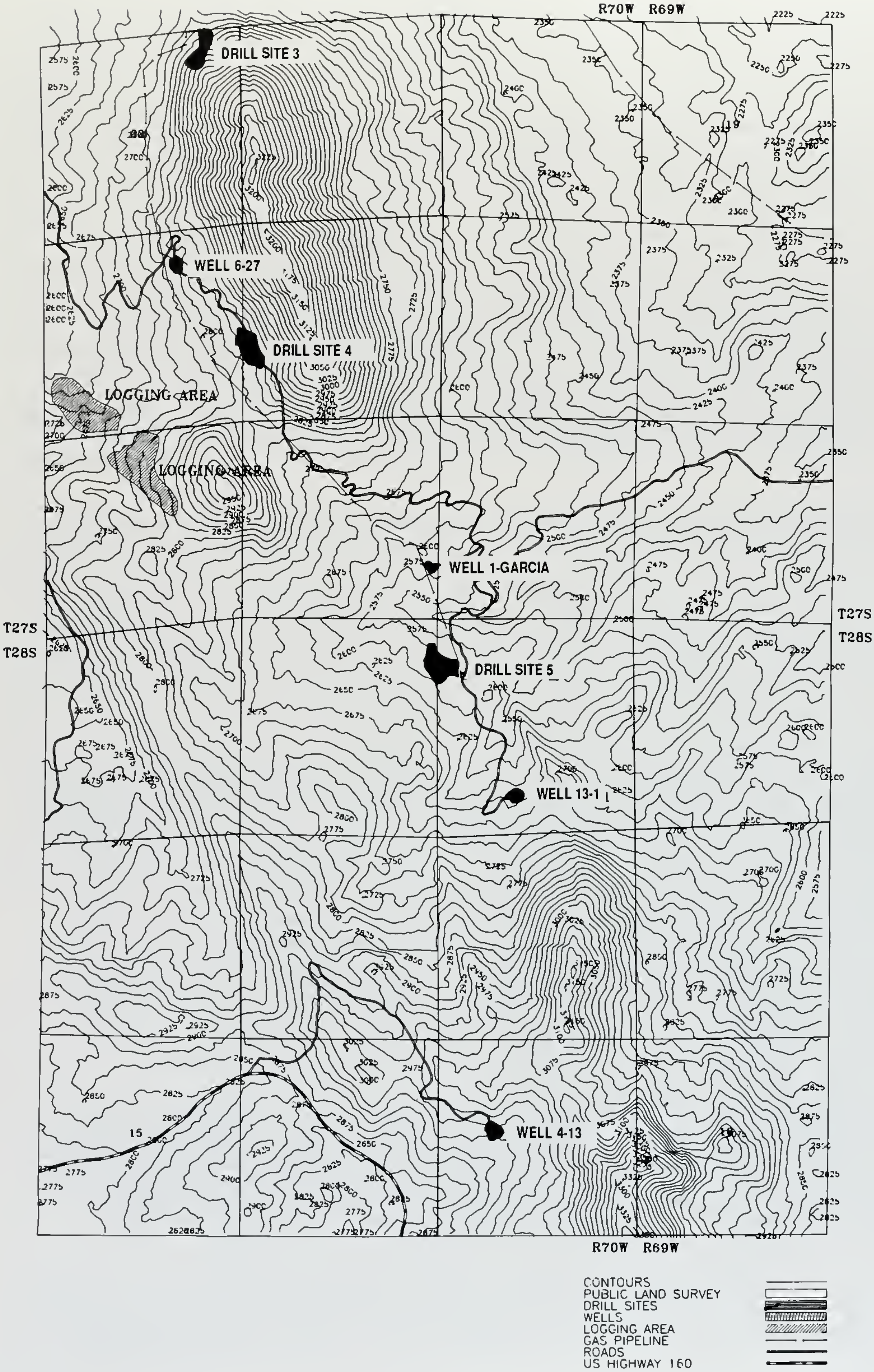

Figure 8. Drill Sites and Wells

The production facility consists of a large three-story building that houses the gas processing equipment. The exterior framing of this facility was completed in May of 1982. These activities created a large amount of disturbance with 10-15 large trucks and earthmoving machines, 5-10 light duty pickups and 30-40 people working on the drill site during May and June of 1982. In addition, numerous trips were made to haul supplies to the site. Construction activities on Drill Site 4 tapered off during May and June of 1983 and 1984. Additional work being completed included installation of flow lines, revegetation of cut slopes, testing of the production facility and minor construction associated with completion of the facilities on the site. The drilling of eight wells in Drill Site 4 was completed in 1982 and 1983 and avoided the critical May-June calving season. In addition, the road between Drill Sites 4 and 5 was not used in 1982, but was used on a limited basis in 1983 and 1984. Use of the road was limited to one trip per day between 8 am and 4 pm as set in BLM use stipulations. In 1985, access was restricted to one trip between the hours of 4 am to 8 am and 4 pm to 8 pm. At all other times, unlimited access was granted.

Construction activities at Drill Site 5 were similar to those at Drill Site 4. Construction of the drill pad extended into the calving season of 1982 and consisted of heavy equipment shaping the drill pad into two levels and the construction of berms and contour ditches on the cut slopes. The exterior frame of the production facility was erected during May and June. Construction required 10-15 earth-moving machines and trucks, 5-10 light duty pickups and 30-40 people at the drill site during the calving season.

Additional activities at Drill Site 5 during May and June of 1983 and 1984 included installation of a flow line from Well 13-1 to Drill Site 5, revegetation work on the drill pad and final construction on the production facility. The drilling of five wells on Drill Site 5 began prior to the 1985 calving season and extended through the May-June time period.

Activity at Drill Site 5 during this time was extremely heavy with drilling occurring 24 hours a day. A crew of 25-35 kept the drill rig operational. Approximately 50 vehicles made round trips from Drill Site 4 to Drill Site 5 each day for transportation of equipment and workers.

An additional unexpected source of disturbance occurred in 1982 near Drill Site 4. A small logging operation began on private land on May 31, approximately 3/4 mi. (.2 km) southwest of Drill Site 4. Logging activities in the area consisted of cutting, skidding, loading and shipping logs out along unimproved roads. Approximately two-three people, two trucks, one tractor (skidder) and one log truck were associated with the operation.

A significant amount of human and equipment construction activity occurred on and in the area of Drill Sites 4 and 5 from 1982 to 1985. This resulted in an avoidance of these areas by calving elk. Avoidance of the drill sites forced cow elk to shift habitat use. At Drill Site 4, a significant shift occurred out of the wet meadow and aspen types (Figure 9). This shift from preferred calving habitat resulted in a corresponding increase in the use of the conifer and mountain shrub types.

At Drill Site 5, the change in habitat use was less apparent; however, the same pattern was evident—a shift to heavier cover types (Figure 10).

The shift of elk distribution to the lower mountain shrub type was supported by the significant change in elevations used by calving elk during the study (Figure 11). Prior to ARCO's development, 14 percent of the elk sightings occurred between 8,000-8,500 ft; however, after development, the use at these elevations increased to 28 percent. There was a corresponding drop in sightings at the 9,000-9,500 ft level. Avoidance of the drill sites forced elk to seek lower habitats in which to calve. Suitable calving habitat was not available at higher elevations.

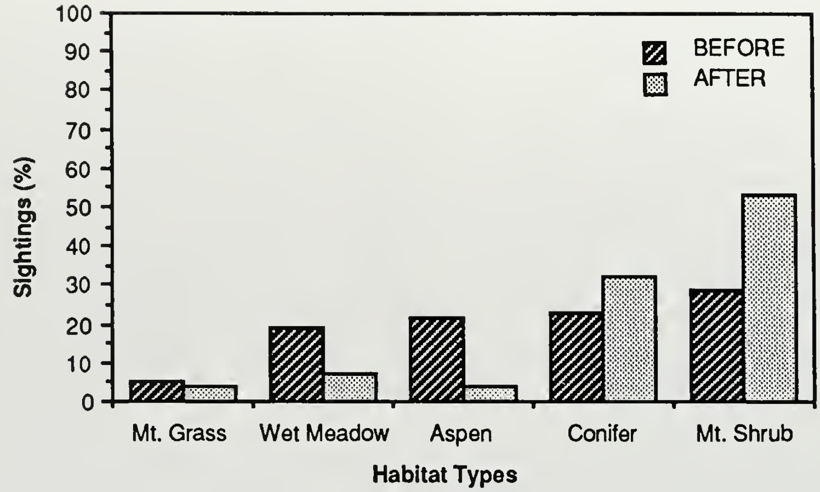

Figure 9. Elk Habitat Use, Drill Site 4

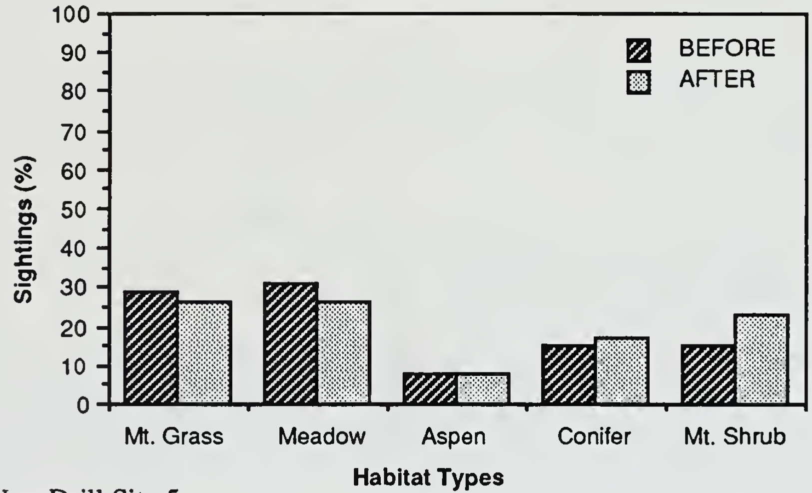

Figure 10. Habitat Use, Drill Site 5

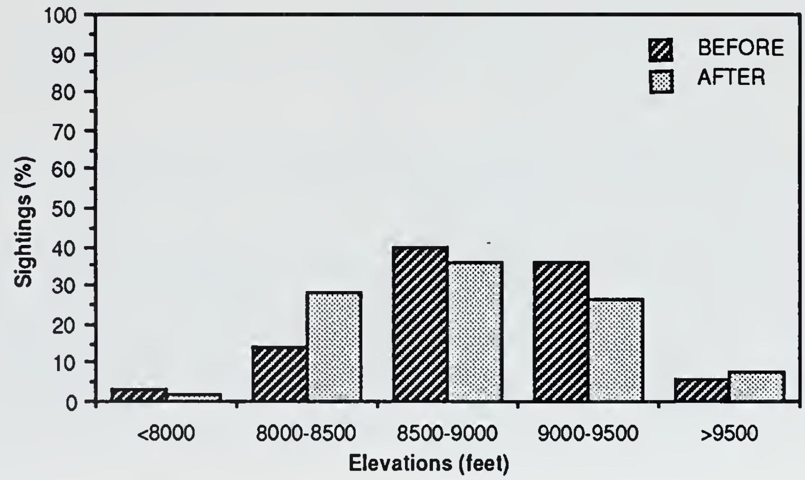

Figure 11. Elk Sightings by Elevation

To determine degree of influence at Drill Sites 4 and 5, 0.25 mi. (0.40 km) zones were developed around the drill sites, out to 1.50 miles (2.4 km) (Figure 12; page 27). Elk sightings were compared within these zones during the six years of study. A significant change in distribution was apparent within 0.50 mi. (0.80 km) of Drill Site 4 (Figure 13). A number of elk were sighted within 0.50 mi. (0.80 km) of the drill site prior to development; however, distribution shifted away from the site when development began. Beyond 0.75 mi. (1.2 km) from the drill site, differences in elk distribution were less apparent.

The same type of analysis was completed for Drill Site 5 (Figure 14). This drill site was located in open habitat and suitable calving areas were located further from the drill site. A shift away from the drill site was evident although change in distribution beyond 0.75 mi. (1.2 km) was less significant (Figure 15).

This information is similar to that collected by Woodward-Clyde Consultants (1983) which indicated that disturbance associated with the presence and activity of construction workers and equipment caused elk to avoid areas located within approximately 3/4 - 1 mi. (1.2 - 1.6 km) of Drill Sites 4 and 5.

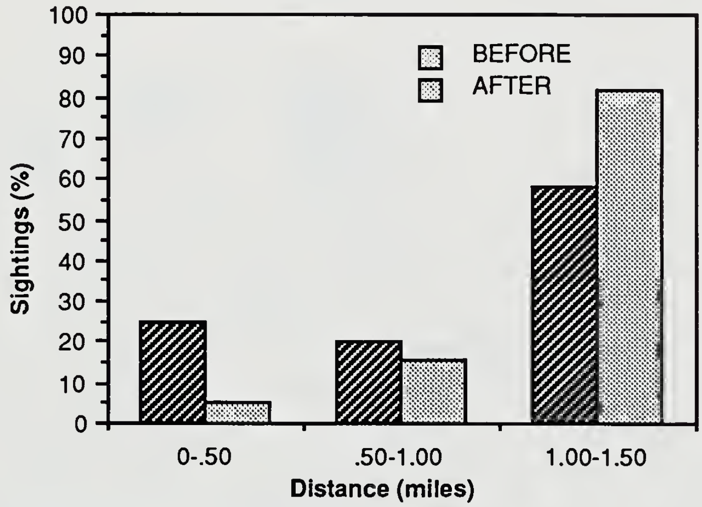

Figure 13. Distance of Elk Sightings From Drill Site 4

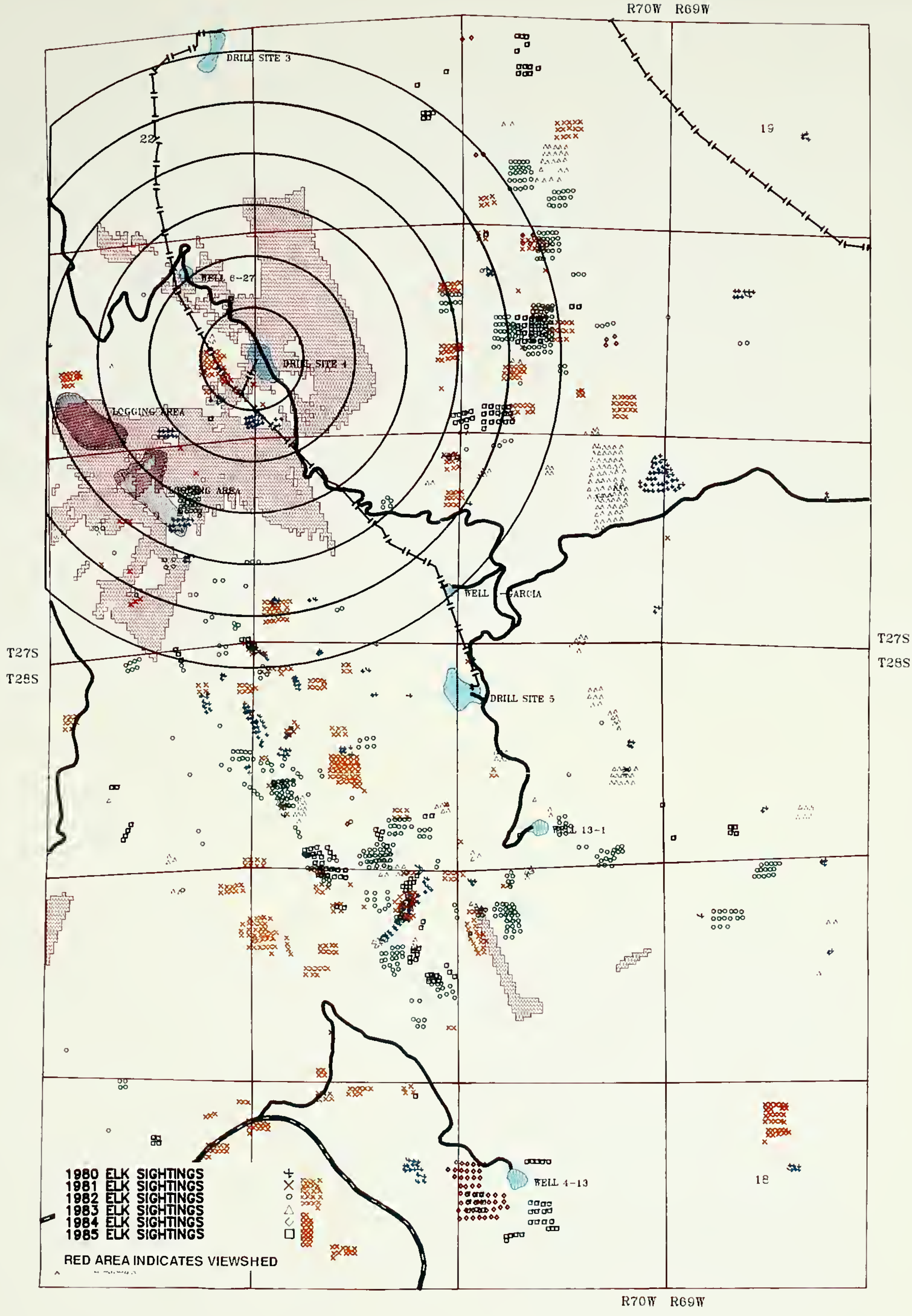

Figure 12. Drill Site 4 Viewshed, Elk Sightings, Zones.

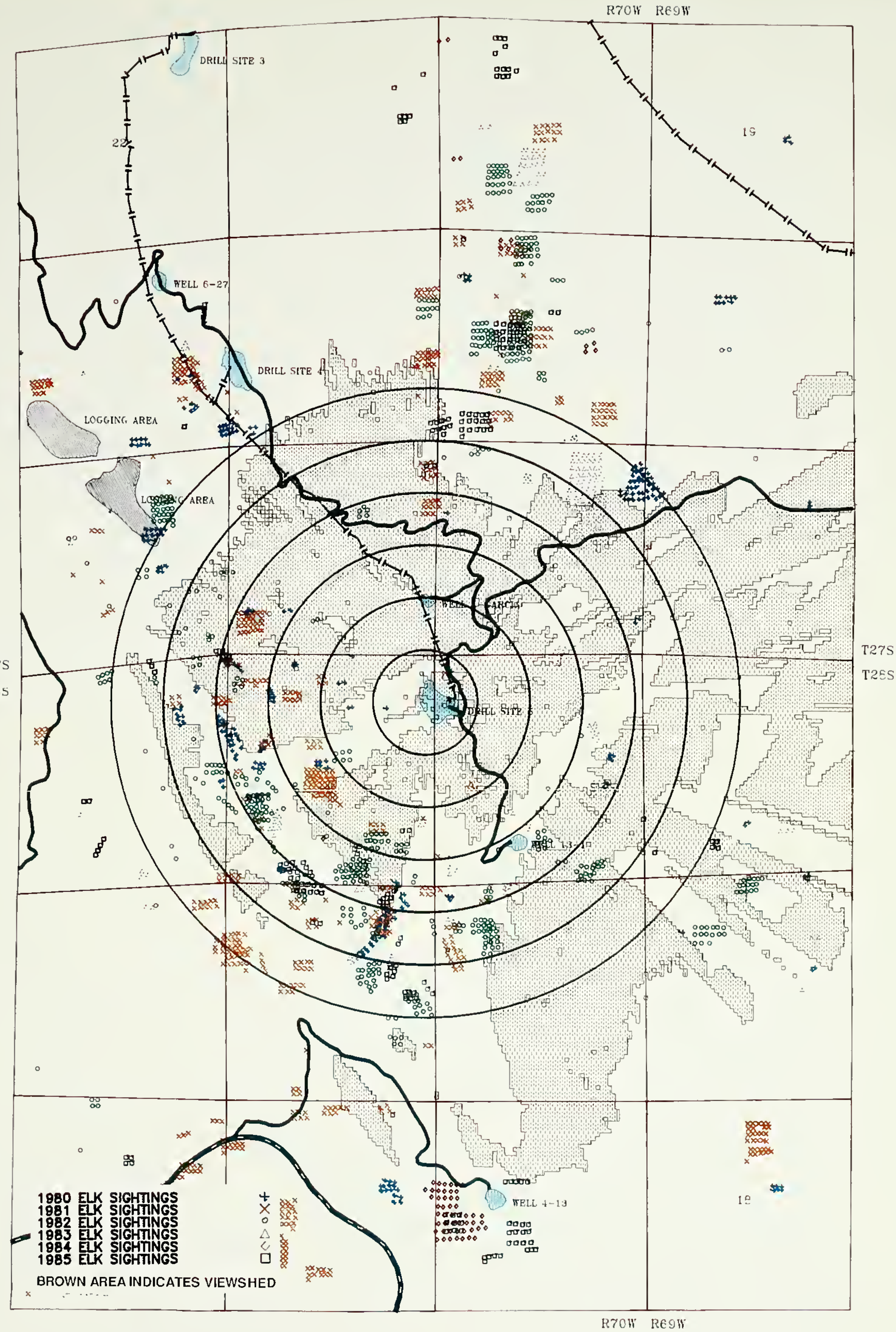

Figure 14. Drill Site 5 Viewshed, Elk Sightings, Zones.

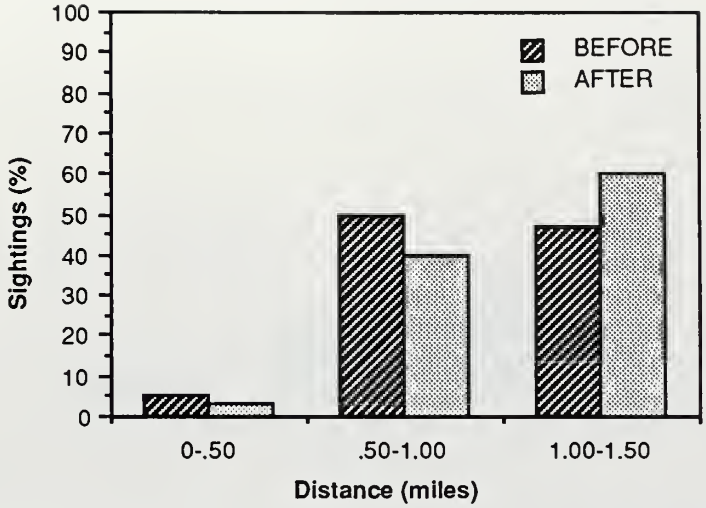

Figure 15. Distance of Elk Sightings From Drill Site 5

Very few elk were recorded in aerial and ground census in the immediate area around Drill Sites 4 and 5 in 1982 compared to 1980 and 1981 (Woodward-Clyde, 1983). Similarly, no calves were recorded in 1982 in these areas in contrast to 1980 and 1981 results. The area around Drill Site 4 was most affected with only 27 elk and no calves recorded in 1982 as opposed to 51 observations with 1 calf in 1980 (LGL, 1980) and 110 observations of elk in 1981 with 3 calves (BLM 1981). This trend continued in 1983, 1984 and 1985 with fewer observations of elk and calves recorded around Drill Sites 4 and 5 than in 1980 and 1981.

As described in the "Methods" section, Digital Elevation Models (DEMs) were utilized to develop a viewshed analysis. The viewshed is the portion of the study area that would be visible from the drill site. This was done to determine changes in elk distribution in those areas visible from the drill sites.

The viewshed analysis for Drill Site 4 showed significant changes in elk distribution (Figure 16). In 1980 and 1981, 34 percent of the total sightings for those years occurred within the viewshed. This dropped to 21 percent in 1982 and 1983 and down to only 7 percent in 1984 and 1985.

The visibility of the drill site had a definite effect on the distribution of elk around Drill Site 4.

The visibility analysis for Drill Site 5 indicates a similar response (Figure 17). The increase in elk sightings within the viewshed in 1982 and 1983, although not significant, is probably due to elk movement from the Drill Site 4 area into the Drill Site 5 viewshed. Disturbances were much greater around Drill Site 4 during this time than around Drill Site 5.

In terms of the amount of disturbance, activity in 1984 and 1985 was greater than any of the previous years on Drill Site 5. A drill rig was operational 24 hours a day during the calving season in 1985. Significantly fewer elk were recorded within the viewshed for these years, apparently due to the disturbances. However,

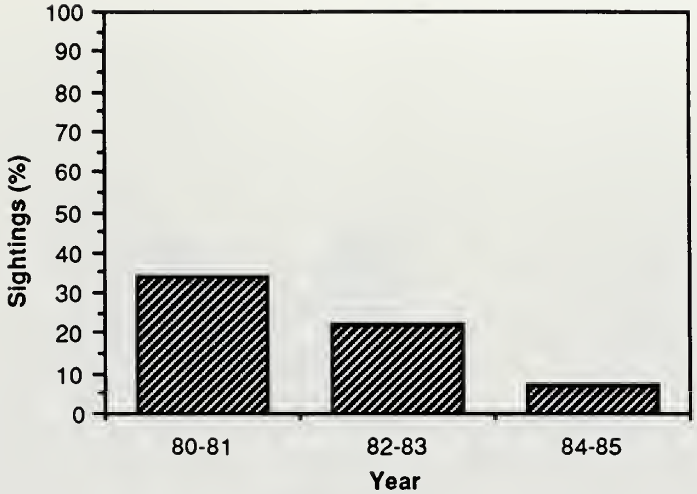

Figure 16. Elk Sightings within Drill Site 4 Viewshed

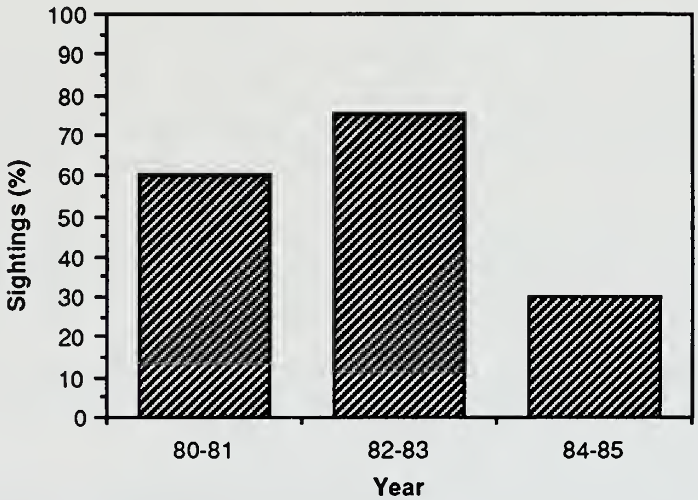

Figure 17. Elk Sightings within Drill Site 5 Viewshed

approximately 80 percent of the elk sightings recorded in the Drill Site 5 viewshed occurred beyond 0.75 mi. (1.2 km) of the drill site. These data indicate that elk distribution is affected beyond .75 mi. (1.2 km) if calving habitats are visible from the drill site.

FINDINGS AND RECOMMENDATIONS

Based on the results and findings of this elk study, several management recommendations were developed.

Findings

1. The population size did not change significantly during the period of study. Early spring surveys of elk on winter ranges indicated that population estimates remain relatively constant.

2. The timing of calving remained constant throughout the study period. Calving dates from this study area were May 20 - July 1. These dates are similar to those reported in other areas of the West.

3. A majority of the elk sightings for the study period occurred on north, northeast and east aspects. This is largely a result of suitable calving habitats located on these aspects.

4. A majority of the elk sightings for the study period occurred on slopes of 10-30 percent.

5. Precalving migration of elk appears to be regulated in time by weather and/or forage phenology. Differences of 2 to 3 weeks in elk migration are possible where annual fluctuations in precipitation are common.

6. The CO_2 development project caused a significant shift in elk distribution around the drill sites located within the calving area:

    a. Elevations used by calving elk changed significantly. Higher elevation habitats were not available which resulted in elk moving to lower elevation calving areas.

    b. The change in elevations resulted in a change in habitats occupied. Preferred calving areas were abandoned in favor of alternate habitat types which provided suitable security cover.

    c. Significantly fewer elk were recorded within 0.75 mi. (1.2 km) of both drill sites after development of the CO_2 field began.

    d. The viewshed analysis completed for both drill sites indicated that elk were displaced to areas where the visibility of the drill site was reduced. Elk distribution was definitely affected by the visibility of the drill sites even beyond .75 mi. (1.2 km).

Recommendations

Based on these findings, the following management recommendations are made:

1. Prior to development in elk calving areas, data concerning traditional use patterns, habitat occupancy and critical habitats should be gathered in order to avoid these areas during development.

2. Development of drill sites, roads and other facilities necessary to support the operation should be completed in the shortest possible time, and during periods of the year when elk are absent.

3. When locating and designing drill sites, roads and facilities, the following guidelines can help reduce impacts and minimize habitat disruption:

   - locate drill sites and roads in areas least used by elk;

   - locate drill sites and roads in areas least visible to elk (e.g., avoid ridge tops, open meadows);

   - avoid habitat components and physical features heavily used by elk (e.g., wet meadows, drainages, drainage heads, saddles and divides);

   - maintain security cover adjacent to roads and drill sites to reduce visibility and lessen noise impacts;

   - dispose of road right-of-way slash to avoid restricting elk movements;

   - revegetate all disturbed areas as soon as possible.

4. Several administrative measures may be taken to reduce disruption to elk during development. The following stipulations were incorporated on this project:

   a. All employees working in the project area were required to attend an Environmental Education Program which was developed and presented by ARCO.

   b. Seasonal (May and June) and permanent road closures were used when appropriate. Closures were enforced with gates and guards.

   c. An ORV plan was completed which restricted use on public lands during the calving season.

   d. On all service roads through the calving areas which were critical to the operation of the project, travel was restricted during the hours of 4 am - 8 am and 4 pm - 8 pm. This restriction minimized traffic during the time when elk were most active.

   e. Speed limits of 25 mph (40 km/h) were enforced and no stopping or standing was allowed while travelling through elk use areas.

   f. Firearms and pets were prohibited in the project area.

The ultimate significance of elk avoidance in terms of reproductive success and population status is unknown. Studies elsewhere have shown that displacement may affect population numbers and quality of animals within a population. Displacement during calving may be especially critical, causing increased mortality in calves, calf development, disease, accidents, and increased competition. Displacement of elk from traditional ranges must be minimized in order to maintain viable populations.

With this in mind, public land managers are faced with the task of maintaining productive elk habitat and providing for energy development. Cooperation and coordination with energy development companies is needed from the early planning stages until project completion in order to ensure elk habitat requirements are met.

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BLM and other entities began a 5-year study of elk calving in south-central Colorado in 1980 to determine the effects of CO_2 drilling and extraction on elk herds in the area. This report describes the methods used in the study and the use of Geographic Information System (GIS) technology to assist in estimating elk response to CO_2 development.

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